

5 **METHODS OF FABRICATING CONTACTS FOR SEMICONDUCTOR
DEVICES UTILIZING A PRE-FLOW PROCESS AND DEVICES MADE
THEREBY**

RELATED APPLICATIONS

10 This application claims priority from Korean Patent Application No. 2002-
81741, filed on December 20, 2002, in the Korean Intellectual Property Office, the
disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND OF THE INVENTION

15 The present invention relates to the fabrication of semiconductor devices, and
more particularly, to the fabrication of contacts for a semiconductor device.

20 As the integration density of semiconductor devices has increased and the
semiconductor devices have been changed into three-dimensional structures, the use
of contact holes having high aspect ratios also has increased. However, when a
contact hole having a high aspect ratio is filled with a conductive material, such as a
doped polysilicon, contact resistance may increase over that of a lower aspect ratio
contact hole. The increased contact resistance may cause power dissipation to
increase which may impede high-speed operations.

25 Fabricating a semiconductor device with a contact hole filled with doped
polysilicon may include forming a gate pattern on a p-type semiconductor substrate.
Next, an n-type impurity region, which may be a source/drain region, is formed in the
semiconductor substrate on both sides of the gate pattern. An interlayer dielectric
(ILD) is then formed on the surface of the semiconductor substrate, and a contact hole
is formed so as to expose a portion of the n-type impurity region. Afterwards, a
contact plug is deposited using a doped polysilicon to fill the contact hole. Thus, the
30 source/drain region, which may be an n-type impurity region formed in the
semiconductor substrate, may be electrically connected to an upper layer formed on
the contact plug.

35 A method of improving contact resistance by treating (*e.g.*, cleaning) the
surface of the source/drain region, so as to decrease a contact resistance between the
source/drain region and the contact plug is disclosed in the U.S. Patent No. 5,534,460
entitled "Optimized contact plug process," dated July 9, 1996. In this method, a

native oxide layer is removed from the inside of a contact hole, and then the contact hole is filled with a doped polysilicon as a contact plug.

SUMMARY OF THE INVENTION

5 Embodiments of the present invention provide for fabricating a contact of a semiconductor device by patterning an interlayer dielectric of the semiconductor device to form a contact hole that exposes a silicon-based region of a first impurity type. The exposed silicon-based region is doped with a gas containing an element of the first impurity type and a contact plug is formed in the contact hole.

10 In particular embodiments of the present invention, the first impurity type is an n-type. Furthermore, the gas containing an element of the first impurity type may be AsH₃ and/or PH₃. Also, the contact plug may be doped polysilicon. The doped polysilicon may be doped with an element of the first impurity type. The element of the first impurity type may be phosphorus and/or arsenic.

15 In further embodiments of the present invention, doping the exposed silicon-based region with a gas containing an element of the first impurity type and forming a contact plug in the contact hole are performed in a chamber of the same manufacturing apparatus in-situ.

20 In still other embodiments of the present invention, the exposed silicon-based region is doped with a gas containing an element of the first impurity type at a temperature of from about 400 to about 800 °C. Furthermore, doping the exposed silicon-based region may be performed under a chamber pressure of from about 6×10^{-2} to about 6×10^{-4} Torr for a time of from about 30 to about 180 seconds.

25 In particular embodiments of the present invention, the silicon-based region is a region of a silicon substrate doped with the first impurity type. The silicon-based region could also be a contact plug. For example, the silicon-based region may be a polysilicon contact plug doped with the first impurity type.

30 In additional embodiments of the present invention, a diffusion layer of the first impurity type is formed in a semiconductor substrate of a second impurity type. An interlayer dielectric is formed on a surface of the semiconductor substrate where the diffusion layer of the first impurity type is formed. In such embodiments, patterning the interlayer dielectric of the semiconductor device to form a contact hole that exposes a silicon-based region of a first impurity type may be provided by

patterning the interlayer dielectric to form a contact hole that exposes the diffusion layer of the first impurity type to provide the exposed silicon-based region.

In yet other embodiments of the present invention, a diffusion layer of the first impurity type is formed in a semiconductor substrate of a second impurity type. A first interlayer dielectric is formed on a surface of the semiconductor substrate where the diffusion layer of the first impurity type is formed. A first contact hole is formed in the first interlayer dielectric to expose the diffusion layer of the first impurity type and a first contact plug is formed in the first contact hole using a doped polysilicon. A second interlayer dielectric is formed on a surface of the semiconductor substrate where the first contact plug is formed. In such embodiments, patterning an interlayer dielectric of the semiconductor device to form a contact hole that exposes a silicon-based region of a first impurity type may be provided by patterning the second interlayer dielectric to form a second contact hole exposing the first contact plug as the exposed silicon-based region.

In additional embodiments of the present invention, a contact structure for a semiconductor device includes an interlayer dielectric of the semiconductor device having a contact hole formed therein that exposes a silicon-based region of a first impurity type. A delta-doped region of the first impurity type is provided in the exposed silicon-based region. A contact plug is provided in the contact hole and on the delta-doped region.

In further embodiments of the present invention, the silicon-based region is a diffusion region of the first impurity type in a substrate of a second impurity type. The diffusion region may be a single crystal silicon region and the contact plug may be doped polysilicon.

In other embodiments of the present invention, the contact structure also includes a first interlayer dielectric having a first contact plug therein. The interlayer dielectric of the semiconductor device having a contact plug formed therein provides a second interlayer dielectric. The contact plug in the contact hole and on the delta-doped region provides a second contact plug. The silicon-based region is provided by the first contact plug in the first interlayer dielectric. In particular embodiments, the first contact plug and the second contact plug are doped polysilicon.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and advantages of the present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings in which:

5 **FIG. 1** is a cross-sectional view of a test element group (TEG) pattern region of a semiconductor device according to embodiments of the present invention;

FIG. 2 is a graph showing effects of the present invention compared with those of the conventional method;

FIG. 3 is a cross-sectional view of a semiconductor device according to embodiments of the present invention; and

10 **FIG. 4** is a cross-sectional view of a semiconductor device according to further embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

15 The present invention will now be described more fully with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein. Rather, these
embodiments are provided so that this disclosure is thorough and complete and fully conveys the concept of the invention to those skilled in the art. In the drawings, the
20 shape and/or size of elements is exaggerated for clarity. Further, it will be understood that when a layer is referred to as being "on" another layer or substrate, it can be directly on the other layer or substrate, or intervening layers may also be present.

FIG. 1 is a cross-sectional view of a test element group (TEG) pattern region of a semiconductor device according to the present invention. Referring to **FIG. 1**, a
25 diffusion layer **110** of a first impurity type (*e.g.*, an n-type diffusion layer) is formed in the TEG region of a semiconductor substrate **100** of a second impurity type (*e.g.*, a p-type semiconductor substrate). Next, an inter-layer dielectric (ILD) **120** is formed on the semiconductor substrate **100**. The ILD **120** may, for example, be an oxide-based layer. The ILD **120** is patterned to form a contact hole, which exposes a portion
30 of the diffusion layer **110** of the second impurity type. Contact plugs **130** are formed in the contact hole using a doped polysilicon. As illustrated in **FIG. 1**, one contact plug is formed according to embodiments of the present invention, while the other contact plug is formed according to a conventional method.

In accordance with particular embodiments of the present invention, a method of forming a first TEG pattern **140A** connected to the contact plug **130** includes forming a pre-flow region **101** by doping the substrate **100** in the contact hole using a gas containing an element of a first impurity type, for example, AsH₃ or PH₃. The pre-flow region **101** may, in certain embodiments of the present invention, provide a delta doped region in the substrate **100**. The pre-flow process is preferably carried out at a temperature of from about 400 °C to about 800 °C under a chamber pressure of about 6×10^{-2} to about 6×10^{-4} Torr for from about 30 to about 180 seconds. The contact plug **130** is formed so as to fill the contact hole, for example, using polysilicon doped with an element of a first impurity type, such as phosphorus (P) or arsenic (As). In this case, the formation of the pre-flow region **101** and the formation of the contact plug **130** may be performed in a chamber of the same semiconductor apparatus, *i.e.*, in-situ.

Thereafter, a titanium adhesive layer (not shown) and a titanium nitride barrier layer (not shown) may be formed on the contact plug **130**. The first TEG pattern **140A** is formed using tungsten on the contact plug **130** where the adhesive layer and the barrier layer are formed.

A second TEG pattern **140B** connected to the contact plug **130** is formed according to conventional methods. In particular, a surface treatment, for example, a cleaning process, is applied to the diffusion layer **110** of the first impurity type, which is exposed by the contact hole. Then, the contact plug **130** is formed so as to fill the contact hole, for example, using polysilicon doped with an element of a first impurity type, such as P or As. After this, a titanium adhesive layer (not shown) and a nitride titanium barrier layer (not shown) are formed on the contact plug **130**. The second TEG pattern **140B** is formed using tungsten on the contact plug **130** where the adhesive layer and the barrier layer are formed.

FIG. 2 is a graph showing contact resistances of contacts formed according to embodiments of the present invention, compared with contacts formed utilizing conventional methods. Referring to **FIG. 2**, the x-axis represents a critical dimension (CD) of each TEG pattern, and the y-axis represents contact resistance with respect to each critical dimension. In the graph, the -▼- line **140B** represents contact resistance for a contact plug that is formed utilizing a conventional method, while the -▽- line **140A** represents contact resistance for a contact plug where a pre-flow process is

carried out according to embodiments of the present invention. Referring to the graph of **FIG. 2**, the TEG pattern **140A** has a lower contact resistance than that of the TEG pattern **140B**. For example, when the CD of the TEG pattern is 110 nm, contact resistance of the first TEG pattern **140A** is improved by 20% over that of the second TEG pattern **140B**.

In particular embodiments of the present invention, the pre-flow gas containing the element of the first impurity type is used to dope to a shallow depth into the surface of the diffusion layer of the first impurity type, thereby forming the pre-flow region **101**. While not being bound by a particular theory of operation, it is believed that the pre-flow region **101** results in the improvement of the contact resistance. That is, the pre-flow region **101** may suppress the growth of a native oxide layer and expedite the epitaxial re-growth during subsequent thermal treatment, thus improving the contact resistance.

FIG. 3 is a cross-sectional view of a semiconductor device illustrating particular embodiments of the present invention. Referring to **FIG. 3**, a trench isolation region (not shown) is defined in a semiconductor substrate **200** of a first impurity type, for example, a p-type semiconductor substrate, utilizing conventional techniques and a gate pattern is then formed. The gate pattern **222**, which includes a gate electrode **228**, a gate upper insulating layer **226**, and a capping layer **224**, can take various forms known to those of skill in the art. An ion implantation process uses the gate pattern as an ion implantation mask to provide a diffusion layer **210** of a first impurity type, for example, an n-type diffusion layer, in the surface of the semiconductor substrate **200** on both sides of the gate pattern **222**. The diffusion layer **210** of the first impurity type corresponds to a source/drain region of an NMOS transistor.

Next, an ILD **220** is formed, for example, by deposition, on the semiconductor substrate **200** where the gate pattern **222** is formed, and is then planarized using, for example, an etchback process or a chemical mechanical polishing (CMP) process. Afterwards, a self-aligned patterning process is performed using the gate pattern so as to form a self-aligned contact hole, which exposes a portion of the diffusion layer **210** of the first impurity type. While formation of the contact hole is described with reference to a self-aligned process, the contact hole may be formed by methods known to those of skill in the art other than a self-aligned patterning process.

The semiconductor substrate **200** where the contact hole is formed is loaded in a chamber of a low-pressure chemical vapor deposition (LPCVD) apparatus. Then, a pre-flow process is carried out. Thus, a pre-flow region **201** may be provided in the substrate **200**. The pre-flow region **201** may, in certain embodiments of the present invention, provide a delta doped region in the substrate **200**, for example, in the diffusion layer **210**. In particular embodiments of the present invention, a gas containing an element of a first impurity type, *i.e.*, AsH₃, is used as the pre-flow gas, and the pre-flow process is conducted at the temperature of about 610 °C under the chamber pressure of about 6×10⁻³ Torr for 60 seconds. After this process, a contact plug **230** is formed using polysilicon doped with As in the same chamber in-situ.

Table 1 shows a comparison of results of on-current of the NMOS transistor and contact resistance of the source/drain region between an NMOS transistor fabricated according to embodiments of the present invention and an NMOS transistor fabricated according to conventional methods.

Table 1:

Item	Present invention	Conventional method	Improvement ratio (%)
On-current	8.44E6[A]	5.49E6[A]	54%
Resistance	3600[Ω]	3980[Ω]	10%

Referring to Table 1, the on-current of the NMOS transistor fabricated according to embodiments of the present invention is improved by about 54% over that of the conventional method, and the contact resistance of the source/drain region is improved by about 10% over that of the conventional method.

The embodiments of the present invention discussed above with reference to **FIGs. 1 and 3** may provide for improved contact resistance between a semiconductor substrate formed of single crystalline silicon and a contact plug formed of silicon. However, as illustrated in **FIG. 4** according to further embodiments of the present invention, contact resistance may also be improved between a first contact plug **330** formed of doped polysilicon and a second contact plug **360** formed of doped polysilicon. Thus, embodiments of the present invention may be utilized with exposed silicon-based regions so as to improve contact resistance to the silicon-based region. As used herein, the term "silicon-based" refers to single crystal silicon and/or polycrystalline silicon.

FIG. 4 is a cross-sectional view of a semiconductor device according to further embodiments of present invention. Referring to **FIG. 4**, a trench isolation layer **302** is defined in a semiconductor substrate **300** of a first impurity type. A plurality of gate patterns **322**, each of which includes a gate electrode **328**, a gate upper insulating layer **326**, and a capping layer **324**, are formed on the semiconductor substrate **300**. As discussed above, different gate patterns may also be utilized. A diffusion layer (not shown) of a first impurity type, for example, a source/drain region, is also formed in the surface of the semiconductor substrate **300**, for example, using the gate pattern **322** as an ion implantation mask.

A first ILD **320** is formed, for example, by deposition, to a thickness sufficient to cover the semiconductor substrate **300** and then planarized. A patterning process is applied to the first ILD **320** so as to form a first contact hole, which exposes the diffusion layer of the first impurity type. A first contact plug **330** is formed in the first contact hole. The first contact plug **330** is preferably formed of a polysilicon doped with an element of a first impurity type, *e.g.*, As. A pre-flow process as described above may, optionally, be carried out prior to formation of the contact plug **330**. If the semiconductor device is a memory device, a structure such as a bit line (not shown) is formed on the semiconductor substrate where the first contact plug **330** is formed.

Then, a second ILD **350** is formed, for example, by deposition, on the semiconductor substrate **300** where the first contact plug **330** is formed and then planarized. The second ILD **350** is patterned so as to form a second contact hole, which exposes the first contact plug **330**. A pre-flow process is applied to the semiconductor substrate **300** where the second contact hole is formed as described above with reference to **FIGs. 1 and 3**. In particular embodiments of the present invention, the semiconductor substrate **300** where the second contact hole is formed may be loaded in a chamber of an LPCVD apparatus. In particular embodiments of the present invention, a gas containing an element of a first impurity type, *e.g.*, AsH₃, is used as the pre-flow gas, and the pre-flow process is conducted at the temperature of about 610 °C under the chamber pressure of about 6×10^{-3} Torr for about 60 seconds. Thus, a pre-flow region **301** is formed on the first contact plug **330**. The pre-flow region **301** may, in certain embodiments of the present invention, provide a delta doped region in the first contact plug **330**. After this process, a contact plug **360** is formed using polysilicon doped with As in the same chamber in-situ.

While the present invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the

5 following claims.